Developing a Wind Turbine Gearbox Load Description

By

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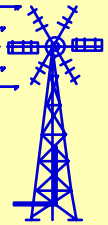
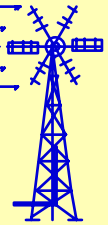


Outline

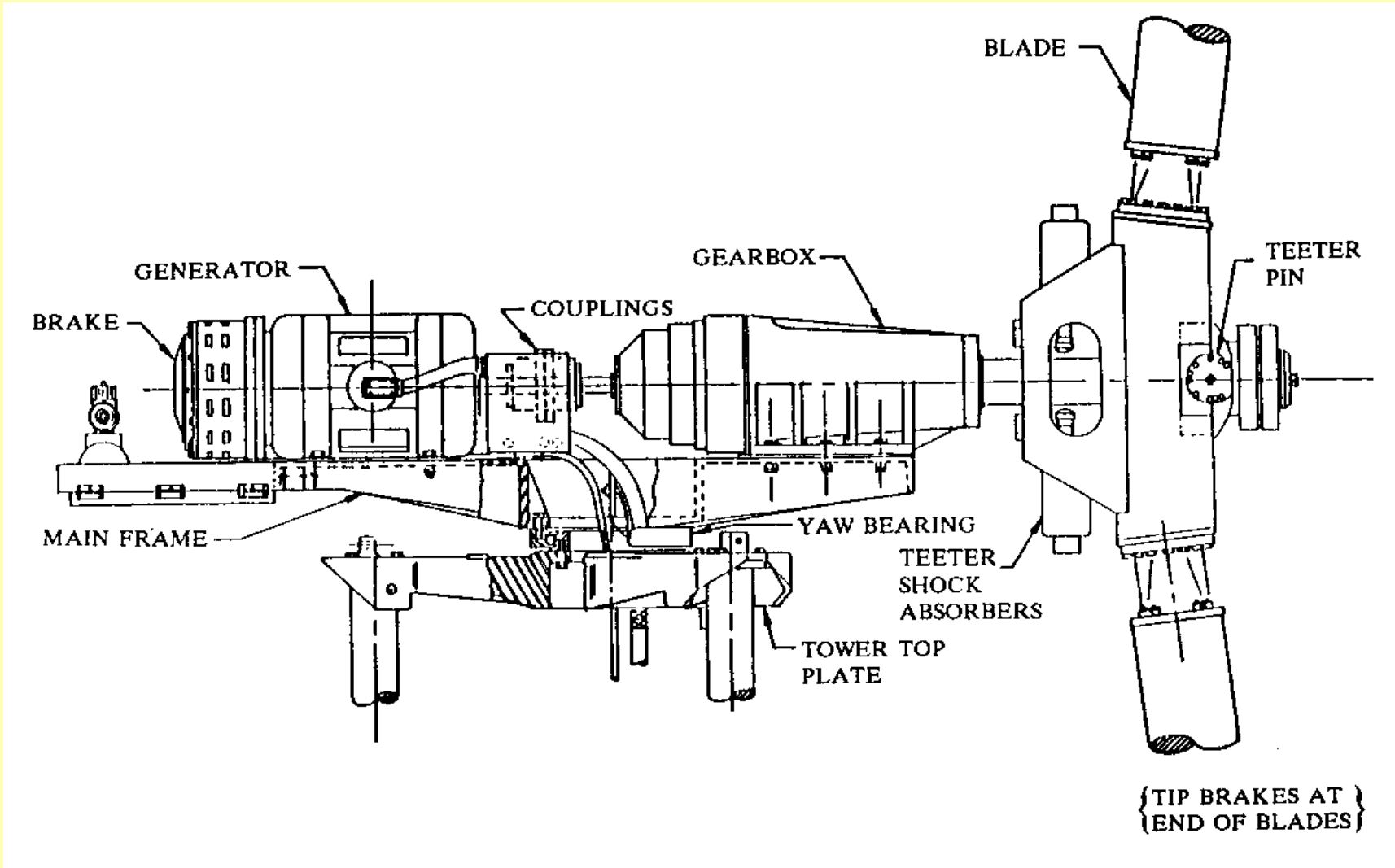
- Loads discussion in 6006 standard
- Topology
- Complex wind inflow
- Aerodynamic, Aeroelastic & Dynamic Analysis
- Design Parameters & Design Load Cases
- Detailing Loads
- Uncertainties



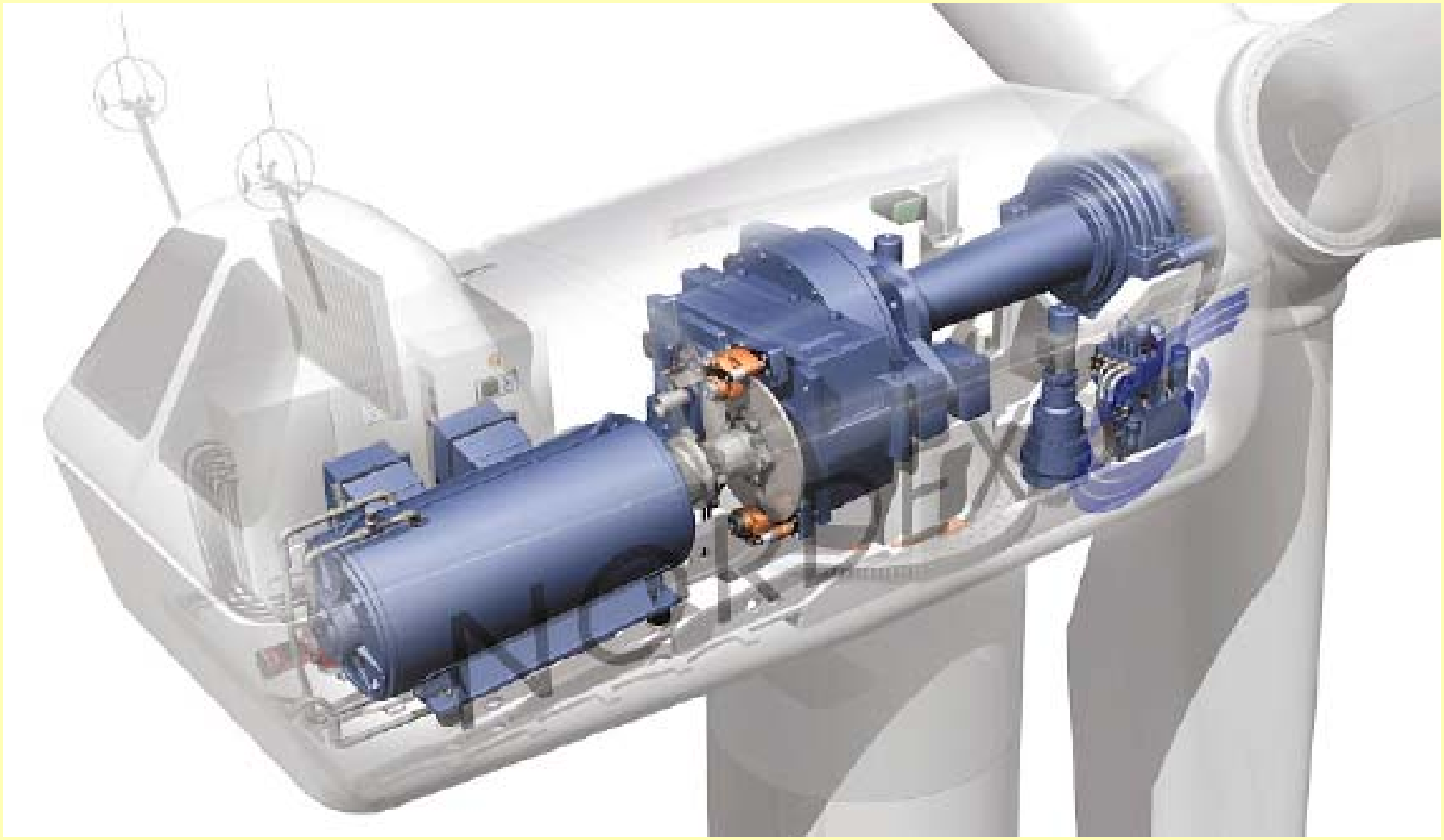
ANSI/ AGMA/AWEA 6006-A03 "Standard for Design and Specification of Gearboxes for Wind Turbines"

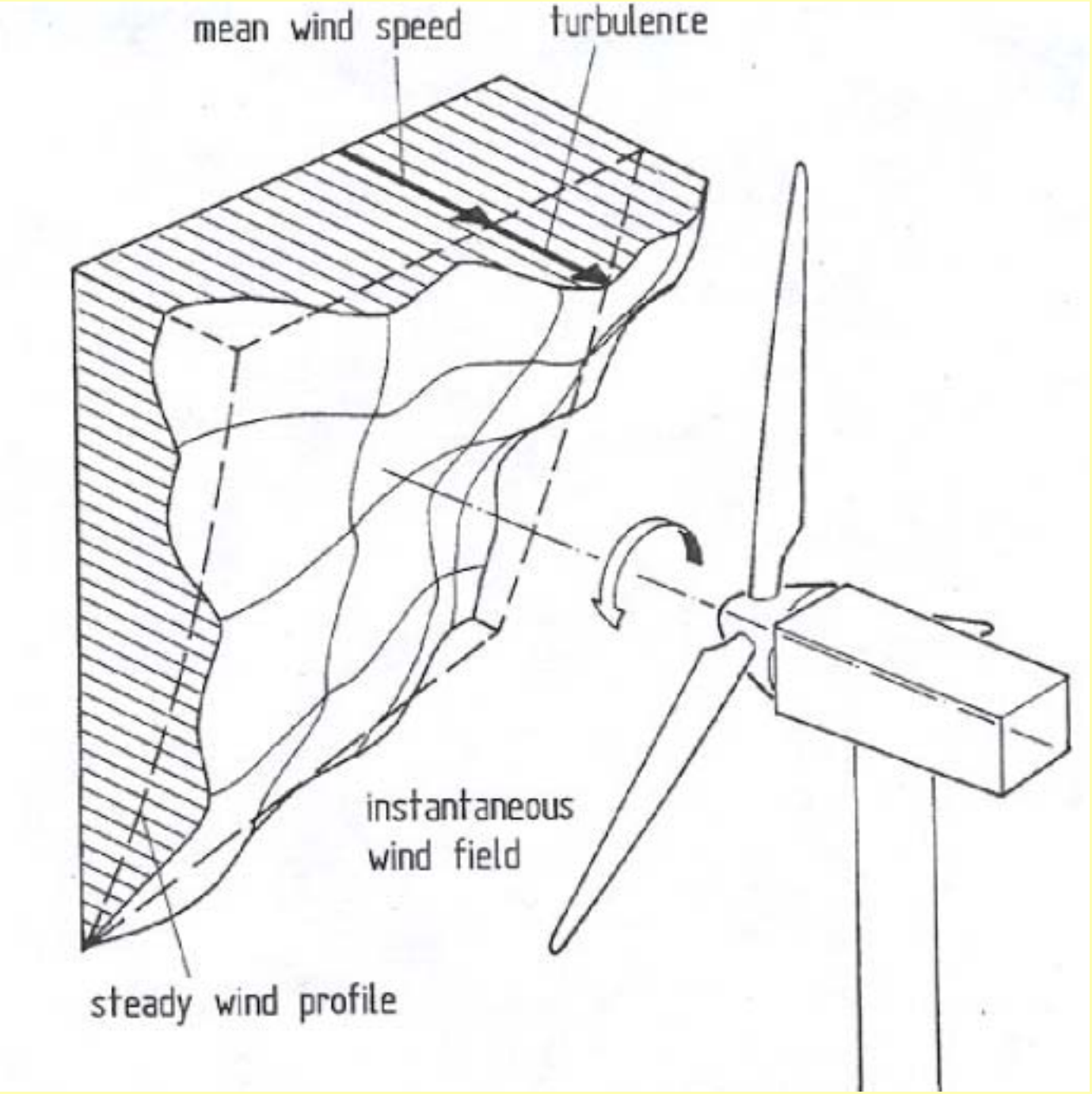
- Documenting collective experience
- failures persist
- design parameters well specified
- method for developing design load is not
- intend to cover this in IEC 61400-4

Bed Plate Mounted Drivetrain



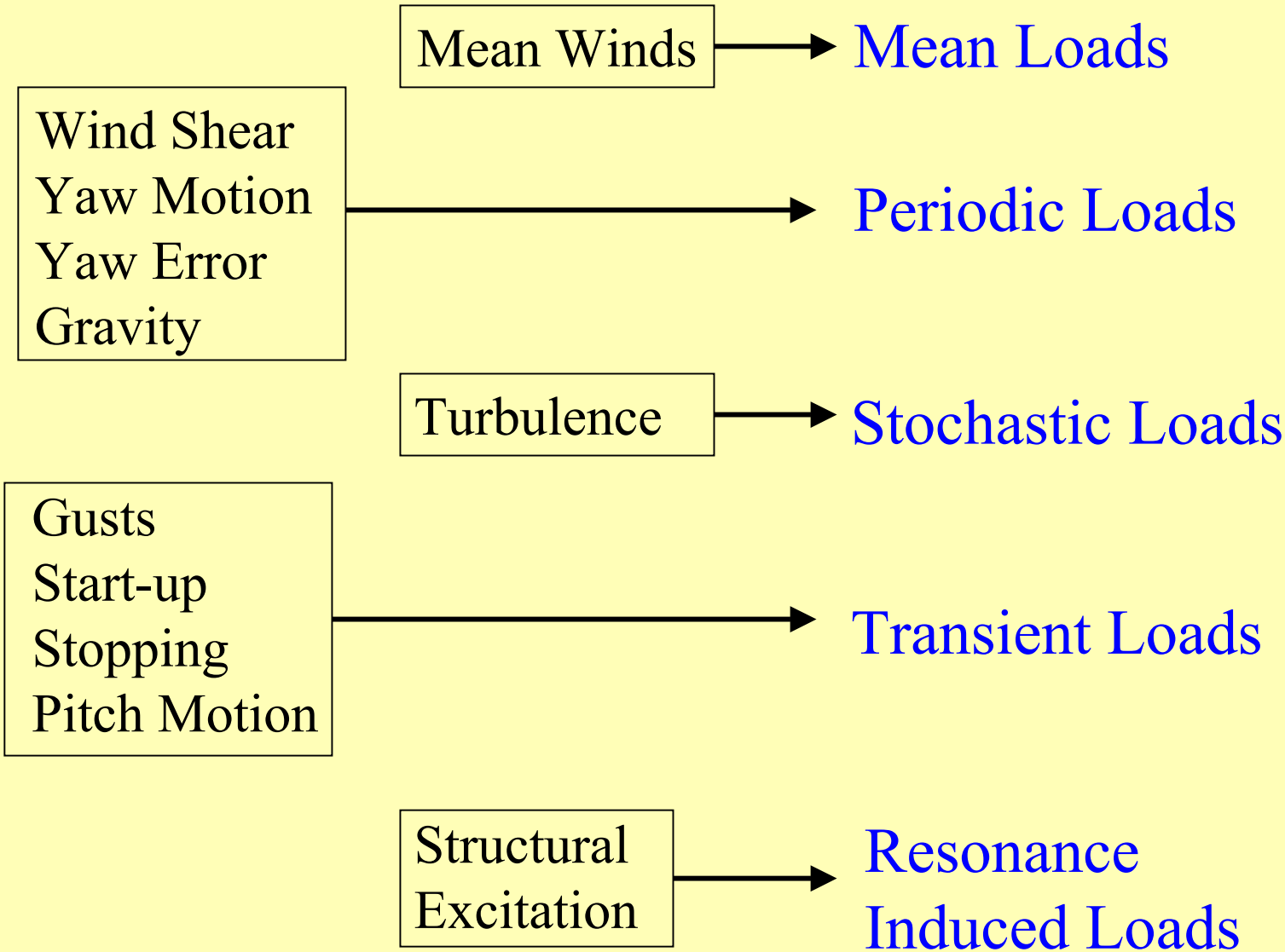
Nordex 60m, 1300 kW



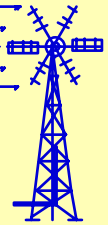


Complex Inflow

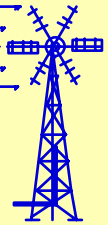
Sources of WTG Loads



WTG Design Load Cases



	Design Situation	Wind Speeds	Other Conditions	Load Spectrum	Type of Analysis	
1	Normal	Vin - Vout		normal	U/ F	N
2	Normal w/ Fault	Vin - Vout	Fault	normal	U/ F	N/A
3	Start-up	Vin - Vout		Time series	U/F	N
4	Normal Stop	Vin - Vout		Time series	U/F	N
5	Emergency Stop	Vin - Vout	Overspeed or loss of line	Time series	U/F	N/A
6	Parked	To extreme	Fault or loss of line	extreme	U	N/A
7	Idling	To extreme	Fault or high wind	extreme	U	N
8	Transport & assembly			incident	U	T/A

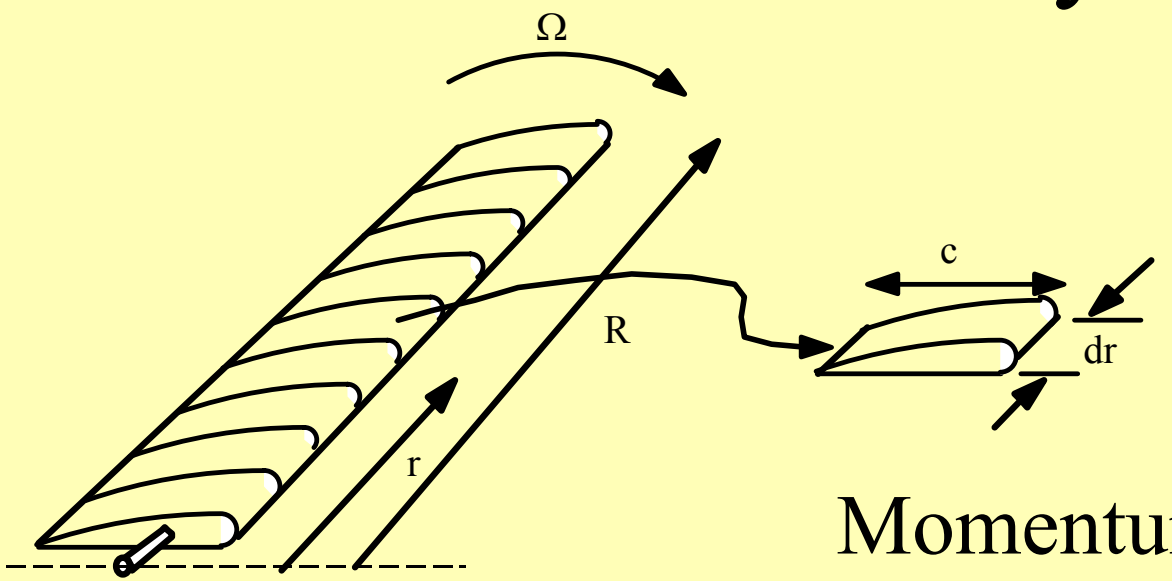


IEC Design Wind Classes

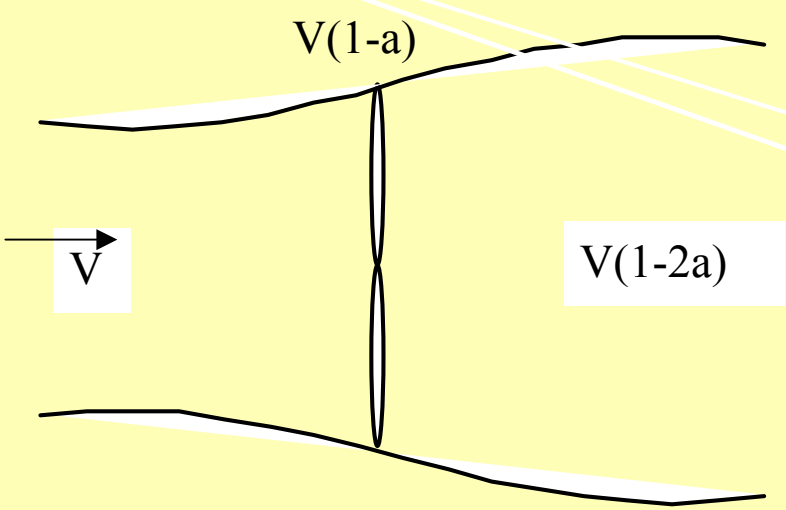
Design Site Characteristic	**Class**			
	I	**II**	**II**	**IV**
Reference Wind Speed, (m/s)	50	42.5	37.5	30
Annual Avg Wind Speed,(m/s)	10	8.5	7.5	6
Turbulence Intensity at 15 m/s, average over 1 yr	0.18	0.18	0.18	0.18

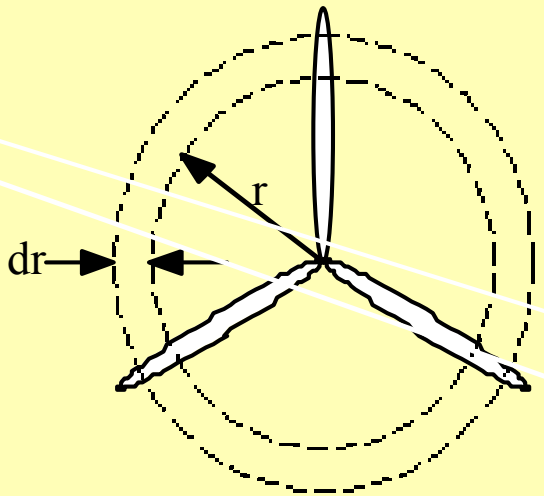
Blade Element Momentum Theory

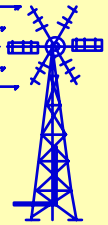
Blade divided into elements



Momentum changes through disc

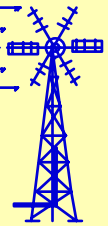






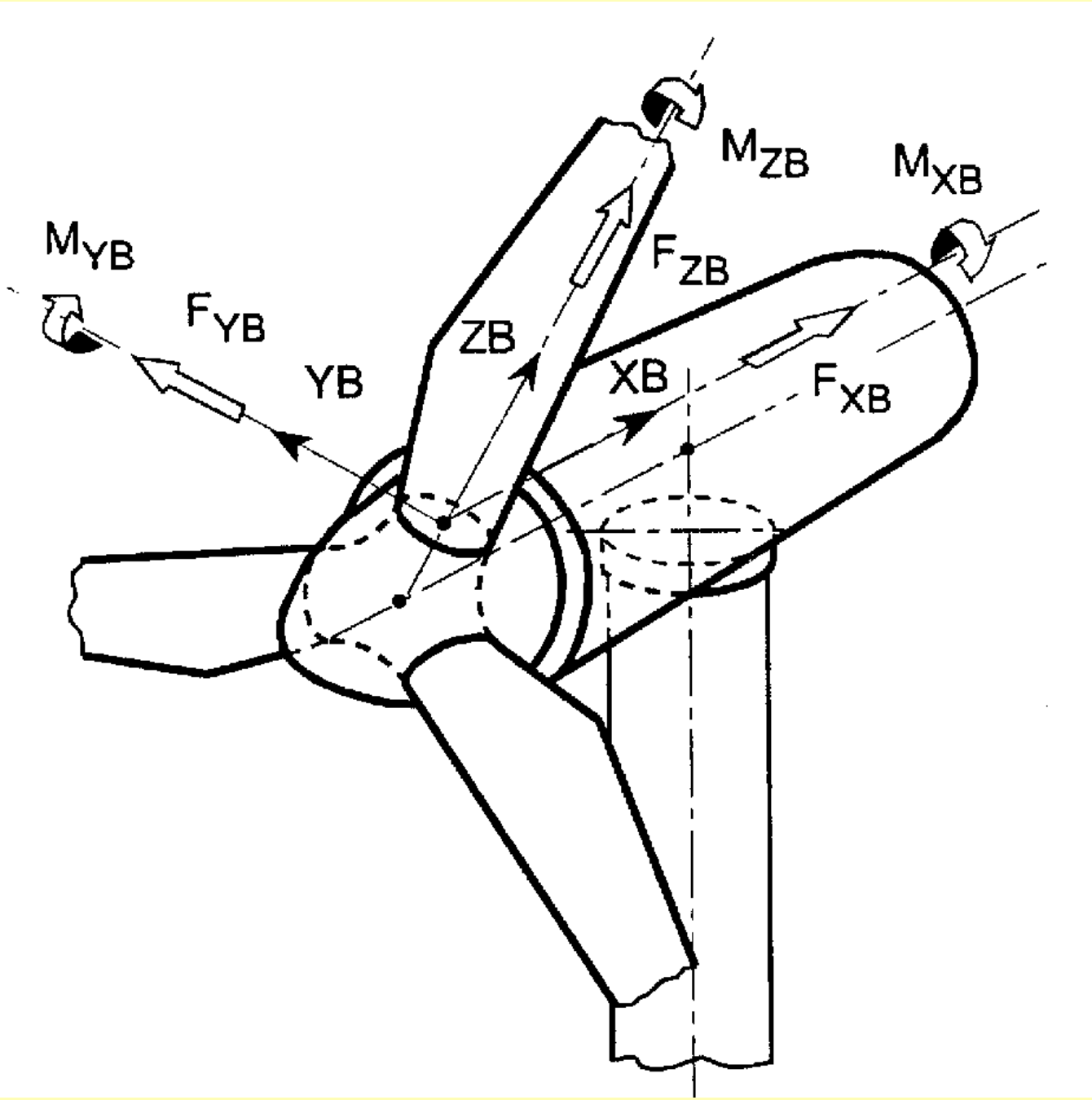
Aeroelastic Model of WTG

- INPUTS:
  - Airfoil data (lift, drag coefficients)
  - Blade geometry (chord, taper, twist, pitch, mass)
  - Rotational speeds
- OUTPUTS (quasi-steady state):
  - Rotor forces and moments at steady state wind
  - power, shaft torque, thrust, shaft moments
- LIMITS
  - did I mention steady state ?

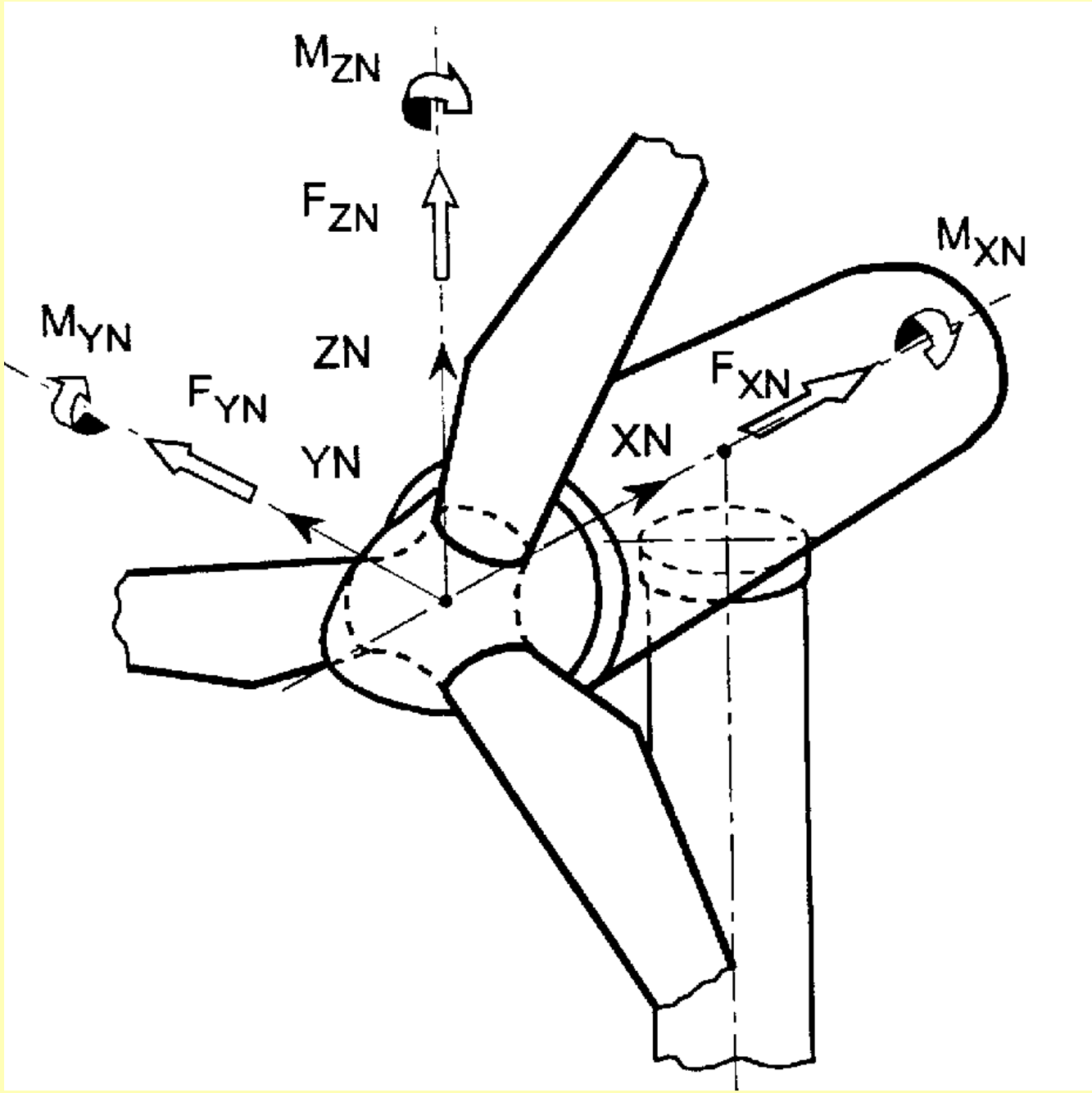


Structural Dynamics Model

- model of WTG operation & structure
- 5 DOF model of each blade
- 5 DOF yaw/ tower top model
- aerodynamic module w/stall & tip models
- Control system model
- Generator models
- Drive train model



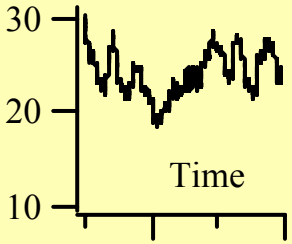
Blade Forces & Moments



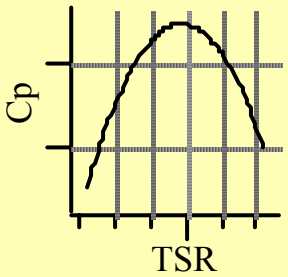
Hub Forces & Moments

INPUTS

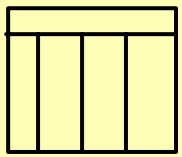
WIND SPEED



CP CURVE

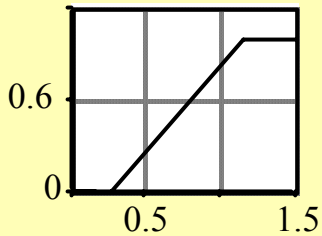


CONFIGURATION



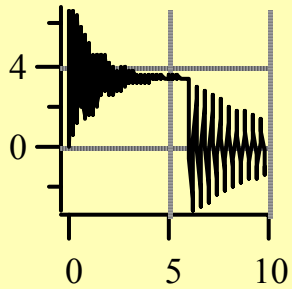
DYNAMIC ANALYSIS

CONTROL

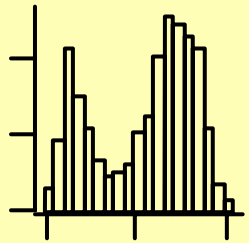


OUTPUTS

TIME SERIES

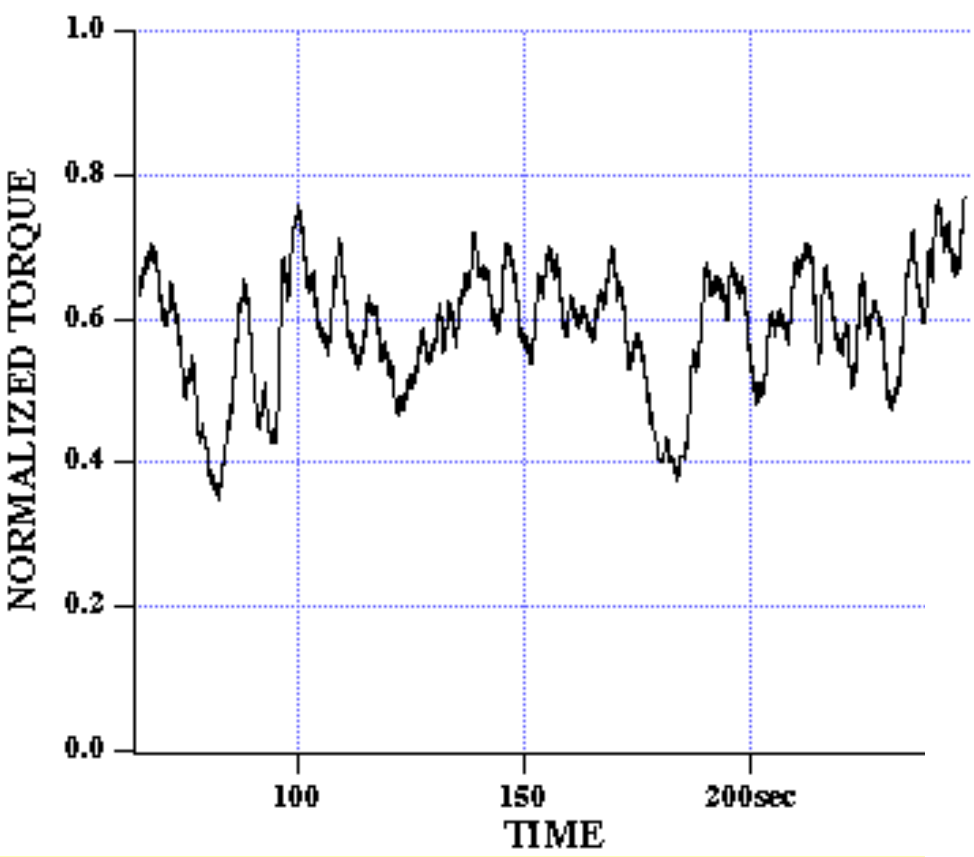


CYCLE COUNTS

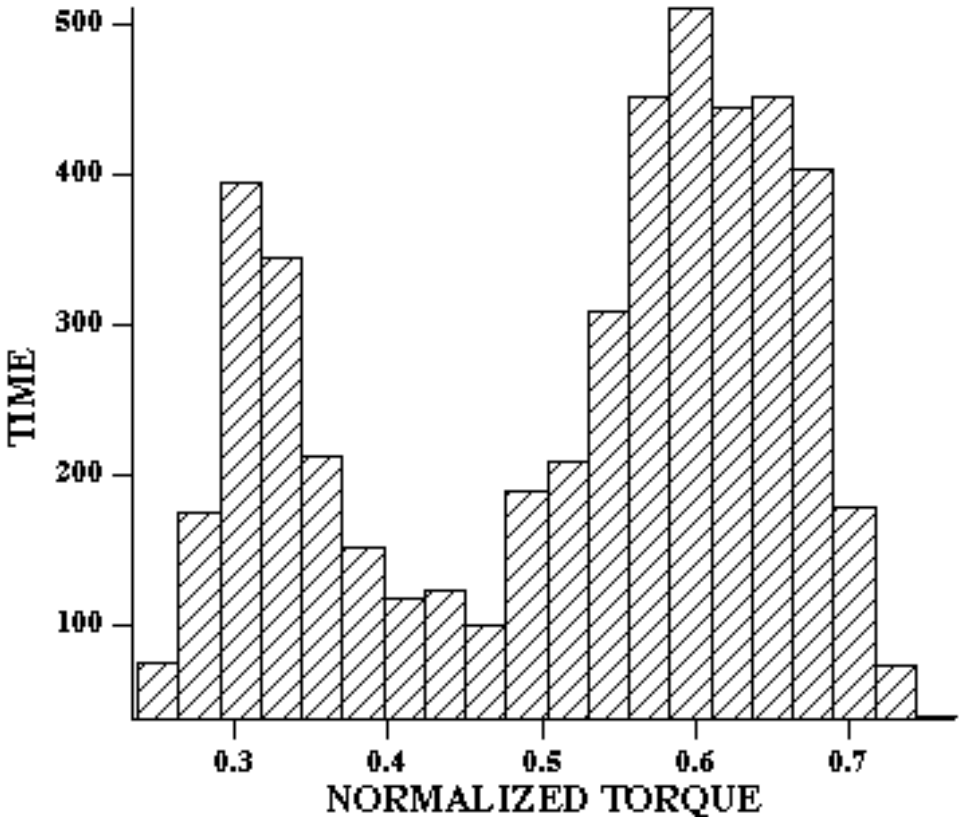


McNiff Light Industry
Wind Turbine Testing and

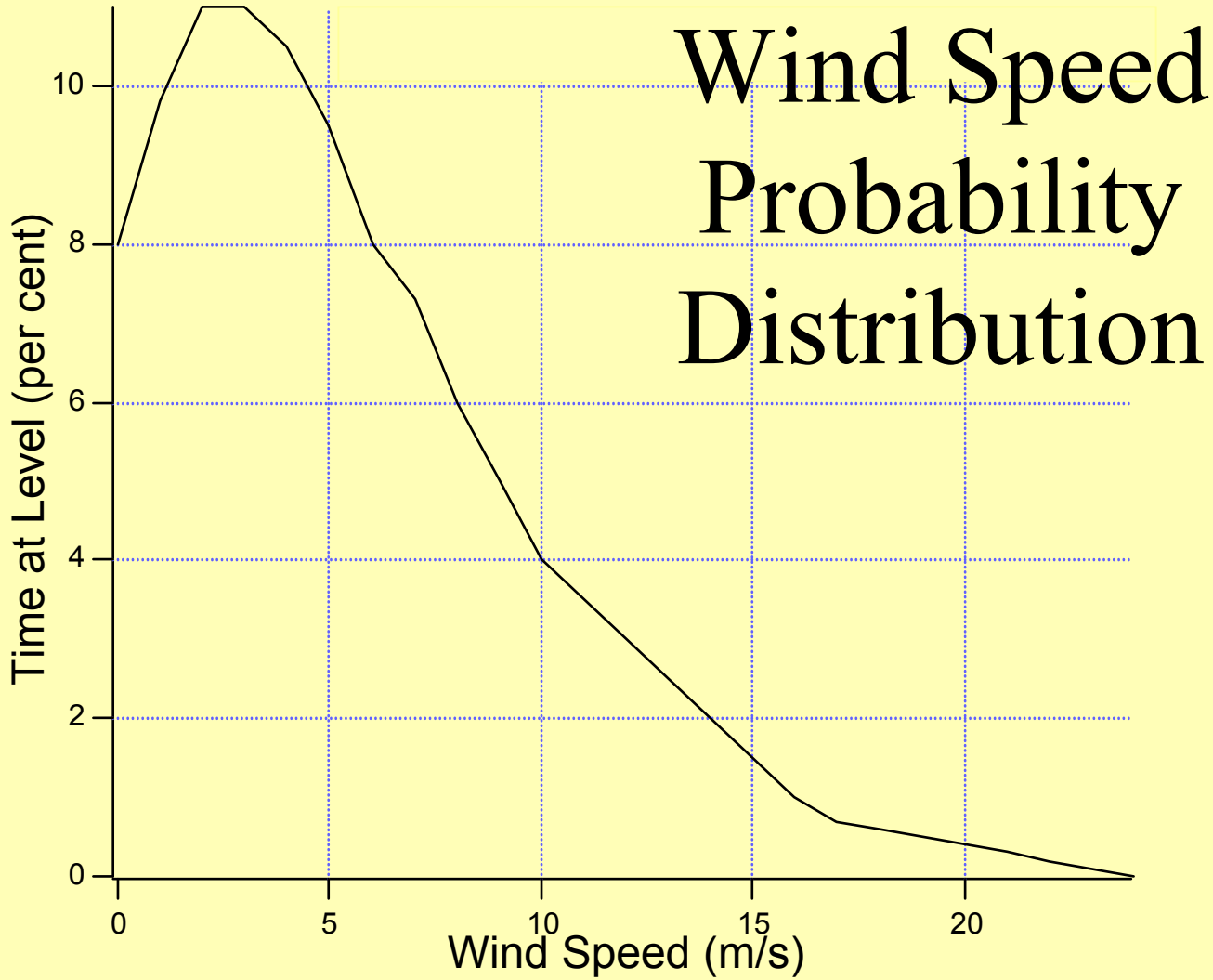
TORQUE TIME SERIES & HISTOGRAM



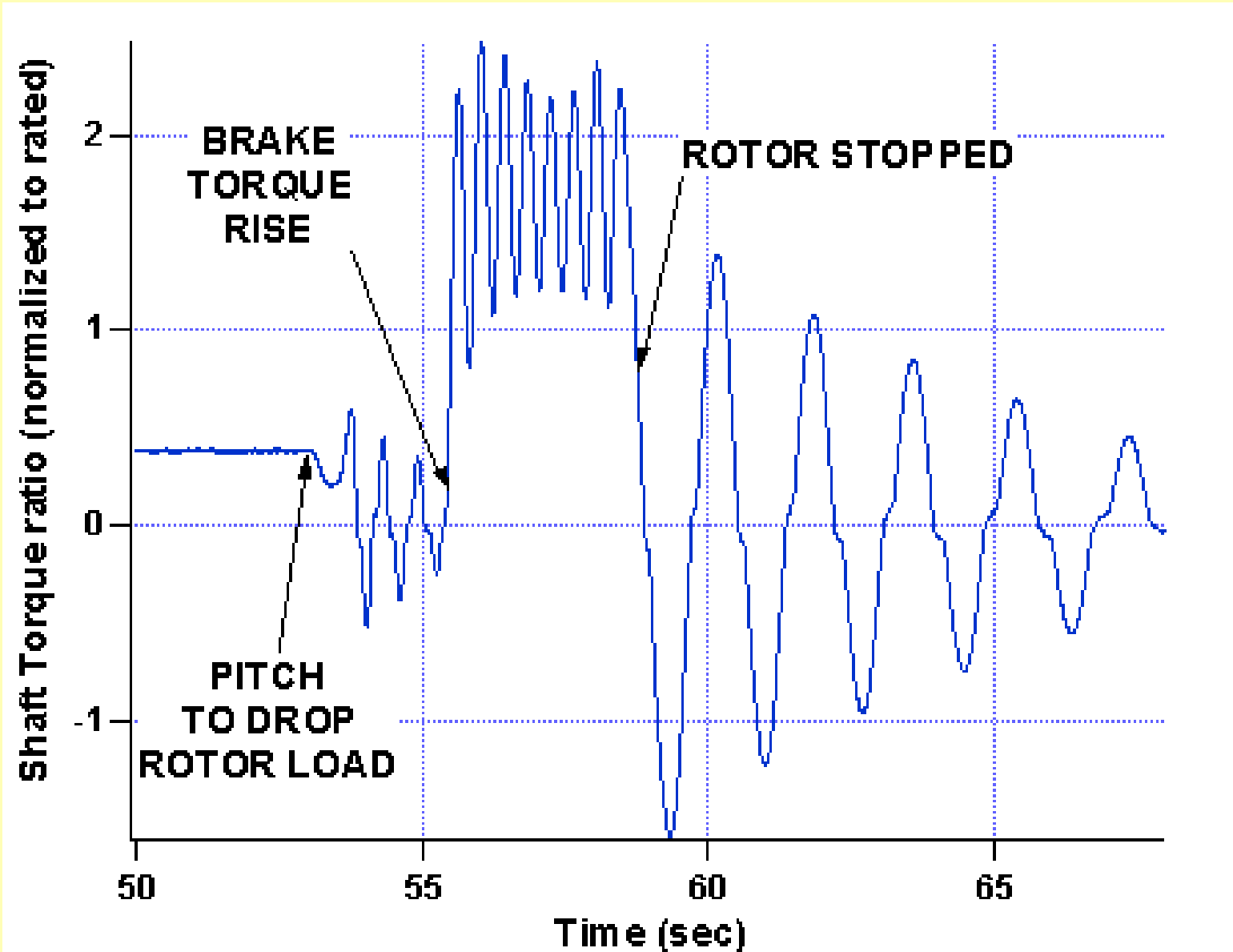
SIMULATIONS for
-- EACH WIND SPEED RANGE
-(ONE HOUR MIN)
-- IEC TURBULENCE CLASS
-- ALL LOAD CASES



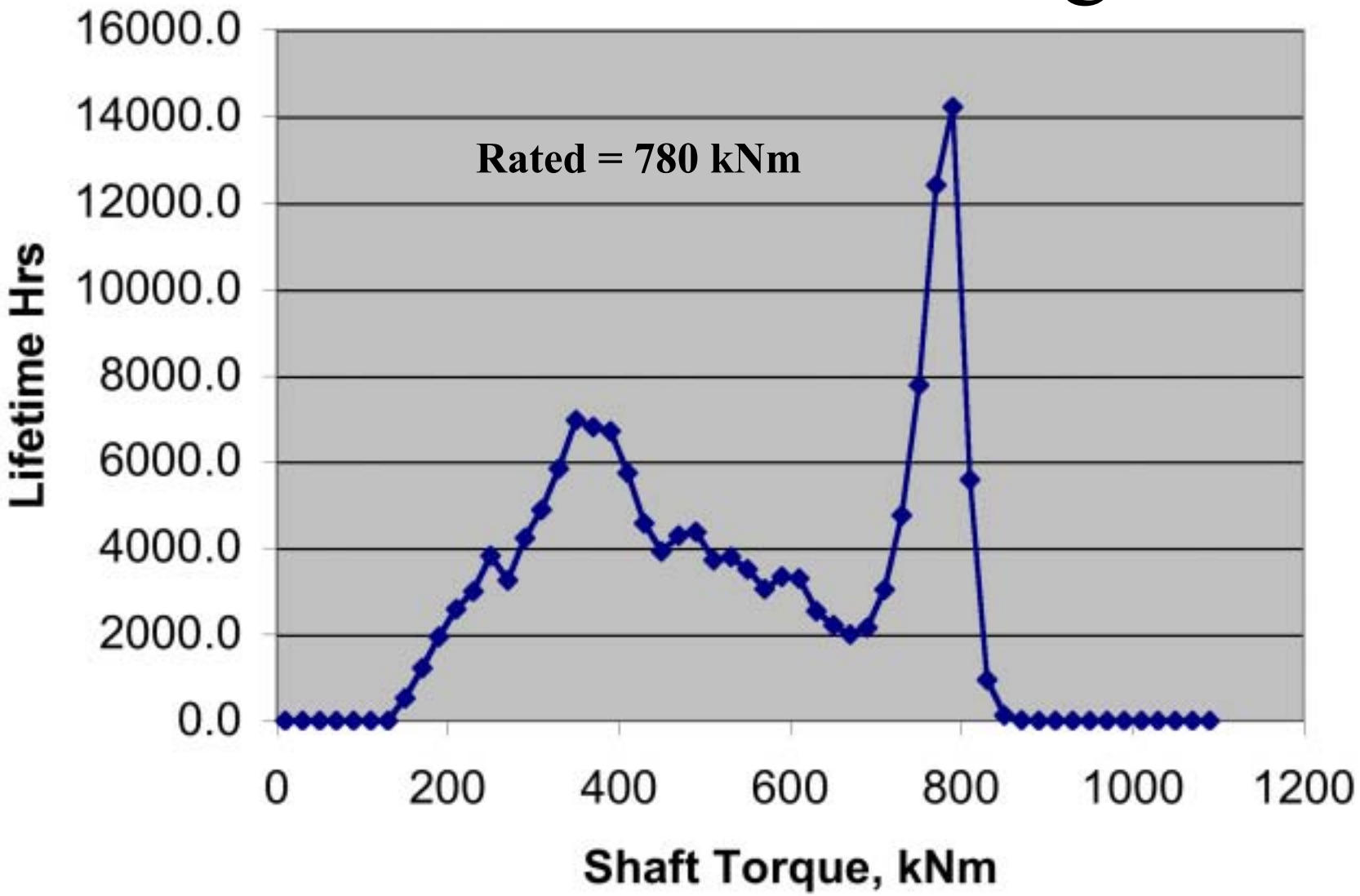
Wind Speed Probability Distribution



Annotated Transient Event

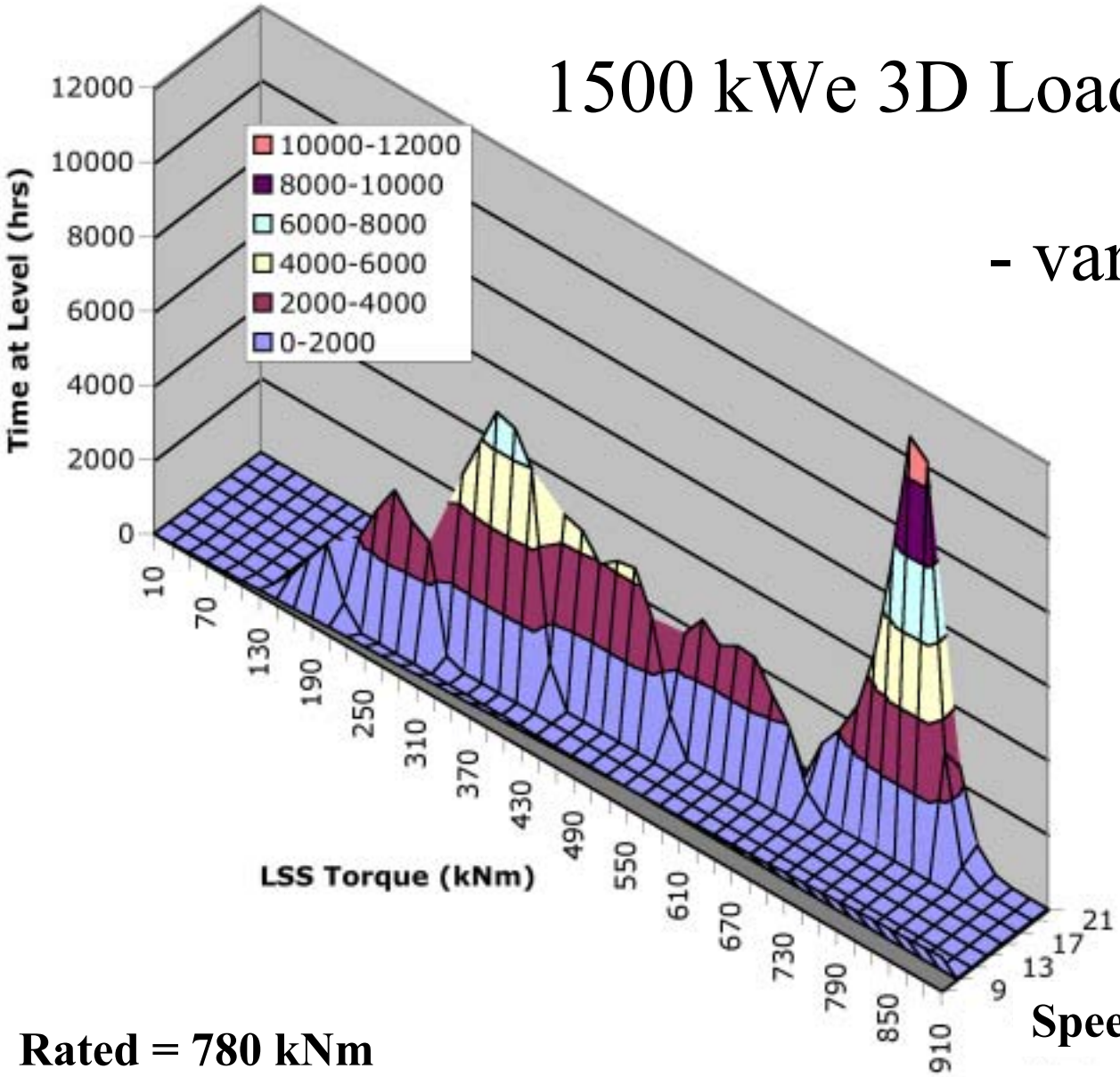


Time-at-Load Histogram



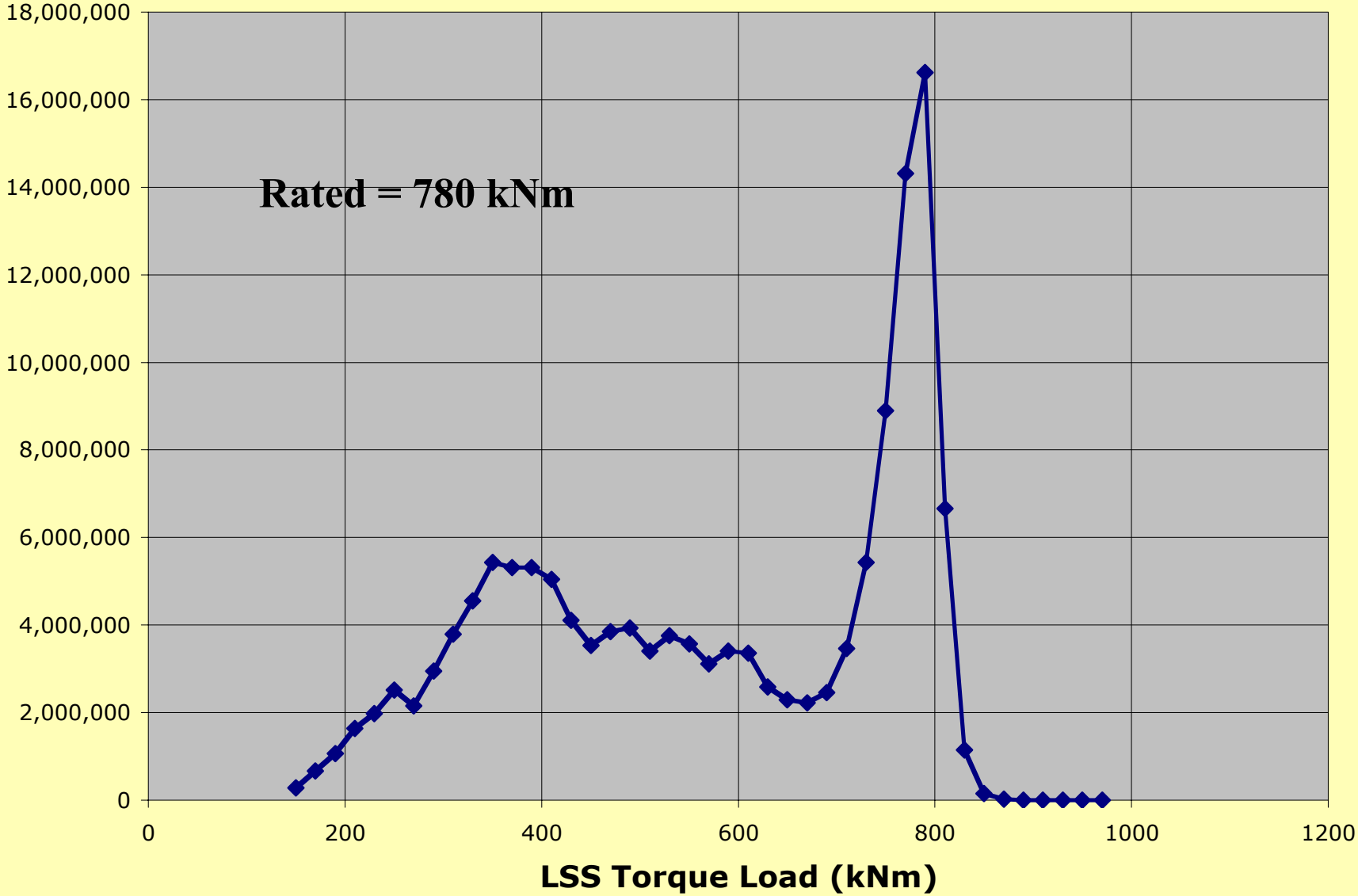
1500 kWe 3D Load Spectrum

- variable speed

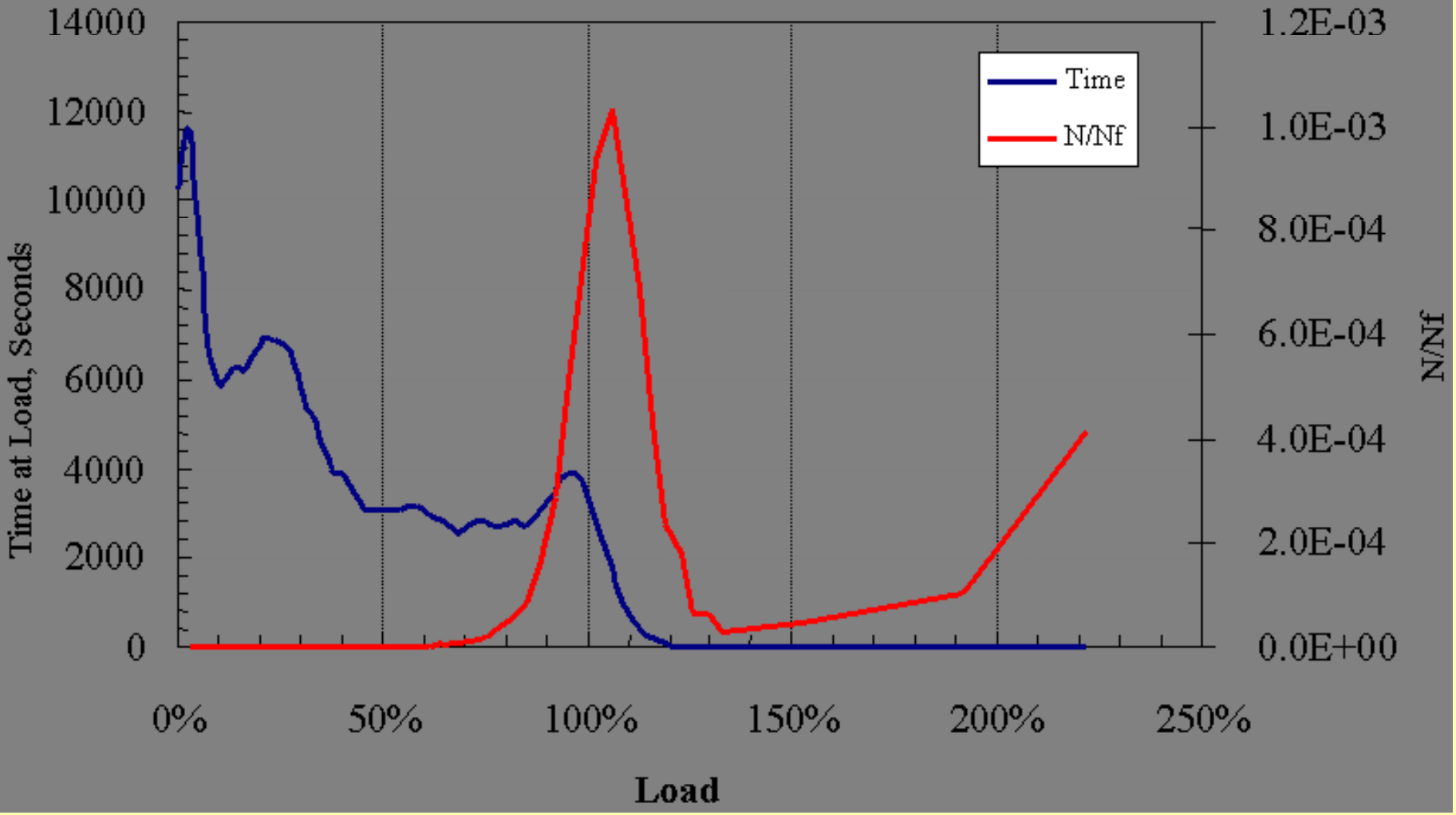


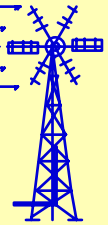
Rated = 780 kNm

Load Histogram - Revolutions



Load Histogram/ Damage Overlay

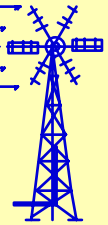




Load Partial Safety Factors

Load Case Type	Factor -Ultimate-	Factor -Fatigue-	Factor -Deflect-
Normal	1.35	1.0	1.35
Abnormal	1.1	1.1	1.1
Transport, erection	1.5	NA	1.5

Assumes validation by measurement



Uncertainties in Loads Analysis

- Unsteady aerodynamics
  - Esp in atmospheric inflow models
- Predictability of control responses
  - Dynamic model inputs
  - Extreme events response at high power
- Codes may be within 50% for new design


Pretty Picture